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MK 12 SURFACE SUPPORTED DIVING SYSTEM (MK 12 SSDS) MIXED GAS, T--ETC(U)
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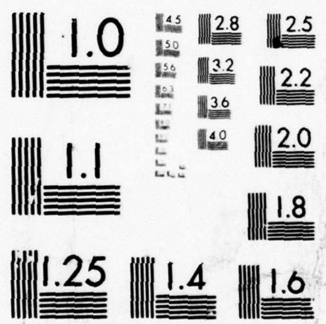

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NAVY EXPERIMENTAL DIVING UNIT REPORT

NO. 19-78

MK 12 SURFACE SUPPORTED DIVING SYSTEM (MK 12 SSDS)

MIXED GAS

TECHNICAL EVALUATION

20 DECEMBER 1978

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BY: MAURICE A, COULOMBE

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Summary of the Technical Evaluation Testing of the MK 12 Surface Supported Diving System, Mixed Gas. Compares required characteristics and operational parameters with test results. Concludes that the system is ready for Operational Evaluation.

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ABSTRACT

The MK 12 SSDS Mixed Gas Technical Evaluation (TECHEVAL) was conducted to determine whether the MK 12 SSDS mixed-gas system functions in a technically acceptable manner and meets design and performance requirements. Developmental, unmanned, and manned testing shows that the MK 12 mixed-gas system can support working divers for extended periods at depths requiring helium-oxygen breathing mixtures; interfaces with existing fleet equipment and safety procedures; and meets the requirements of SOR 46-54. The MK 12 SSDS Mixed Gas TECHEVAL was satisfactorily completed and with completion of minor equipment modifications is ready for Operational Evaluation (OPEVAL).

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SECTION 1

INTRODUCTION

1.1 SCOPE

This report documents the Technical Evaluation (TECHEVAL), Project Number 131-1-DT-IIIG, of the MK 12 Surface Supported Diving System (SSDS) mixed-gas (helium-oxygen) configuration. The purpose of TECHEVAL was to determine whether the MK 12 mixed-gas system functions in a technically acceptable manner and meets design and performance specifications. The evaluation shows the MK 12 mixed-gas system (1) supports divers performing hard work for extended periods at depths requiring helium-oxygen breathing mixtures, (2) interfaces with existing fleet diving equipment and safety procedures, and (3) conforms to physical, technical, and mission characteristics and requirements specified in the Specific Operational Requirement (SOR) 46-54 (reference 1).

The scope of the evaluation ranges from unmanned research and development tests through manned testing to show operational effectiveness and suitability in the following areas.

(a) Diver mobility
(b) Dive duration
(c) Communications intelligibility
(d) Life support reliability
(e) Mission reliability
(f) Maintainability
(g) Availability
(h) Logistics supportability
(i) Compatibility
(j) Interoperability
(k) Training requirements
(l) Environmental impact

1.2 BACKGROUND

The MK 12 SSDS was designed and developed to serve as the U.S. Navy's basic tethered system for use in nonsaturated diving operations (figure 1). The U.S. Navy conducted a commercial equipment survey in 1971; development of the MK 12 began in 1972 to satisfy SOR 46-54 requirements.

During July and August of 1973, prototype testing of an experimental development model produced poor results, prompting system redesign (see reference 2). NEDU was designated the developing agency. From June 1973 to June 1975, selected system components were redesigned and tested separately

Figure 1. MK 12 SSDS mixed-gas configuration.

against system standards (reference 3). All tested components were satisfactory except the recirculator assembly. Therefore, TECHEVAL was scheduled in two parts: (1) the air configuration, January to March 1976 and (2) the mixed-gas configuration, September to November 1978. Dress items designed and tested from July to December 1975 proved satisfactory. Air configuration TECHEVAL was successfully completed on schedule with a total of 276 dives, no aborts, and all requirements satisfied (reference 4). The MK 12 air configuration successfully passed Operational Evaluation (OPEVAL) (reference 5), was certified, and approved for service use in November 1977.

Recirculator component testing became a secondary priority until completion of the air TECHEVAL. In February 1976, recirculator research and development began with analysis of prior problems yielding new solutions. Satisfactory unmanned test results were obtained in December 1976 (see reference 6). Manned saturation tests in February 1977 indicated that the recirculator could provide adequate system flow although canister duration was extremely limited (reference 7). Unmanned testing continued until required canister durations were achieved (references 8 through 16). In cold water manned testing at NEDU Ocean Simulation Facility (OSF) in November 1977, canister durations improved but failed to meet the design goals (reference 17). It was concluded from unmanned testing (reference 15) that initial cooling of exhaust gas with subsequent gas rewarming within the CO_2 absorbent bed led to drying of the absorbent material and deterioration in performance. The recirculator assembly was modified by incorporation of two moisture retaining condensors within the body of the canister and the use of high-water content CO_2 absorbent. Extensive manned duration testing in January and February 1978 (reference 18) demonstrated a minimum 9-hour duration with less than 0.5% CO_2 Surface Equivalent Value (SEV) in 15 FSW at a mean water temperature of 35° F. On 6 February 1978 recirculator design freeze was declared and preproduction prototypes were then fabricated. In June and July of 1978, during a saturation dive at the OSF, the MK 12 was manned tested in 40° F water at 390 FSW using a work-rest sequence simulating a moderate work rate and achieved canister durations in excess of 10 hours (reference 19). On 27 September 1978 the MK 12 began reliability testing in accordance with the MK 12 TECHEVAL TEST PLAN (reference 20).

1.3 DESCRIPTION

The MK 12 SSDS mixed-gas diving configuration comprises the air MK 12 SSDS issue equipment, the modular mixed-gas recirculator assembly, and associated support equipment. The equipment variations used in the mixed-gas configuration are discussed under the major assemblies.

1.3.1 Helmet Assembly

The MK 12 helmet (figures 2, 3, and 4) was designed for use with either air or mixed gas as the breathing medium, requiring a minimum amount of parts conversion. The basic helmet shell is molded fiberglass coated with yellow Gelcoat. The shell is fitted with a bronze base for strength. Four shatterproof plastic (Lexan) viewports provide visibility comparable to that of SCUBA. Major helmet subassemblies and their functional descriptions for mixed-gas operations are listed below.

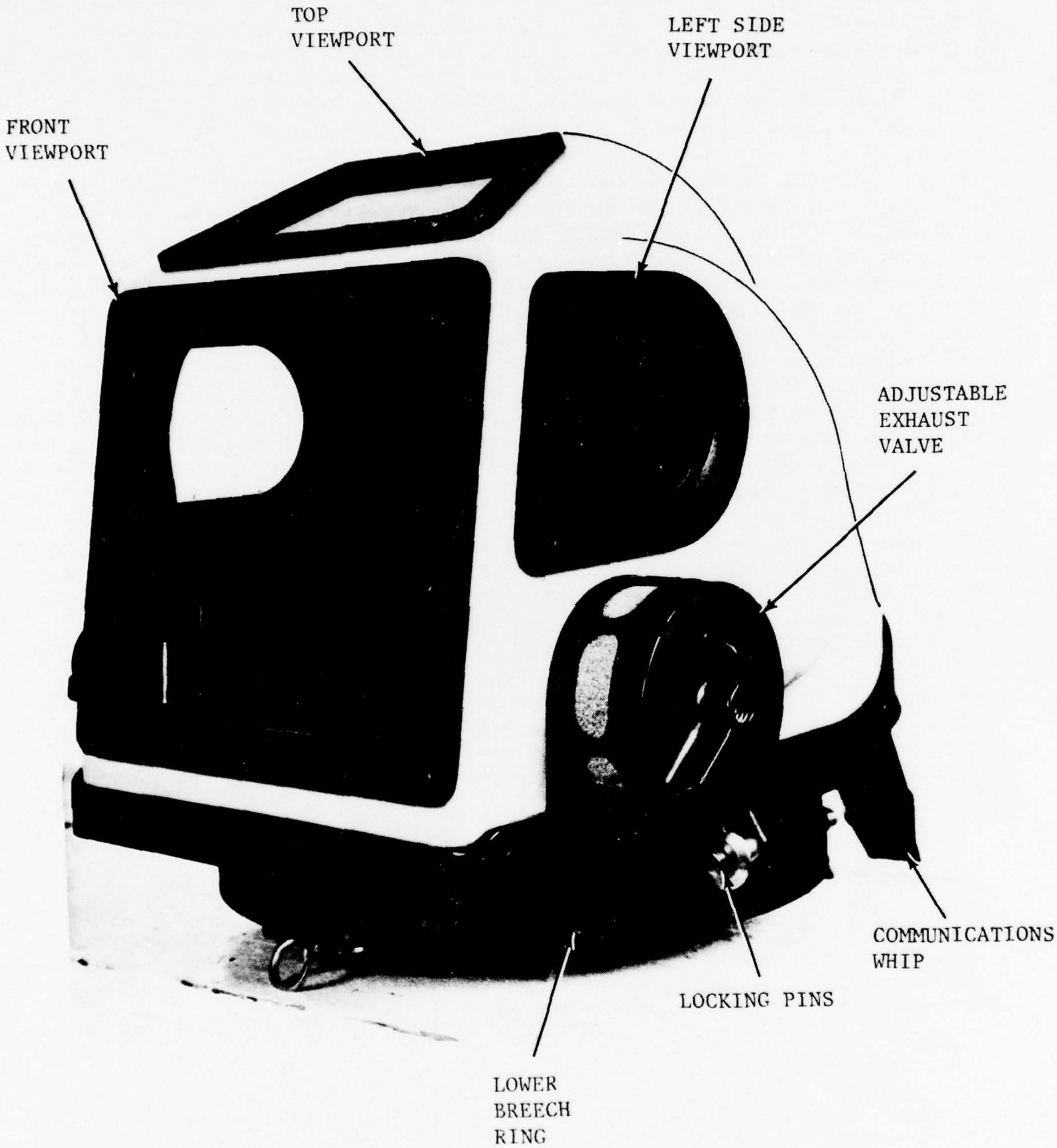

Figure 2. MK 12 SSDS helmet (left side view).

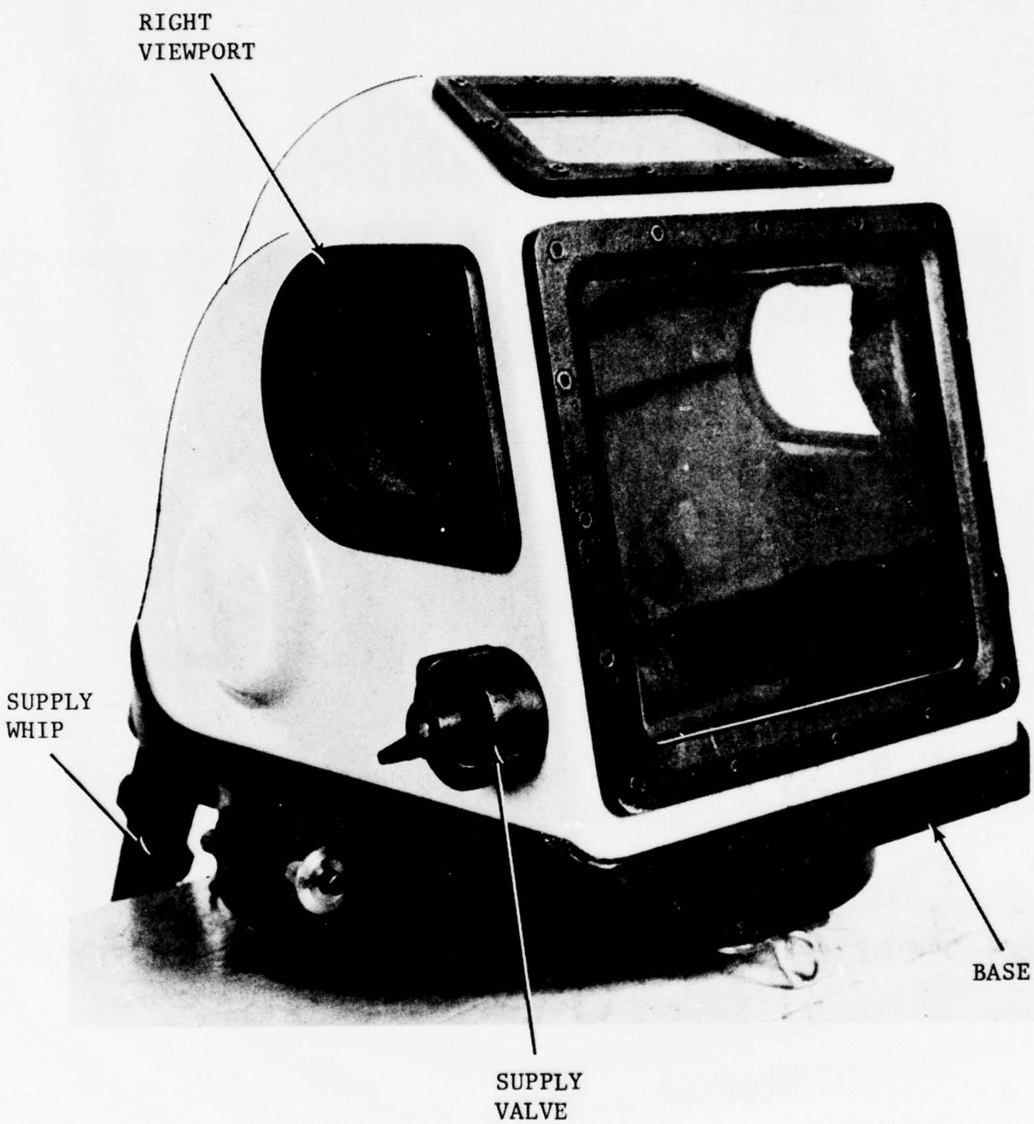

Figure 3. MK 12 SSDS helmet (right side view).

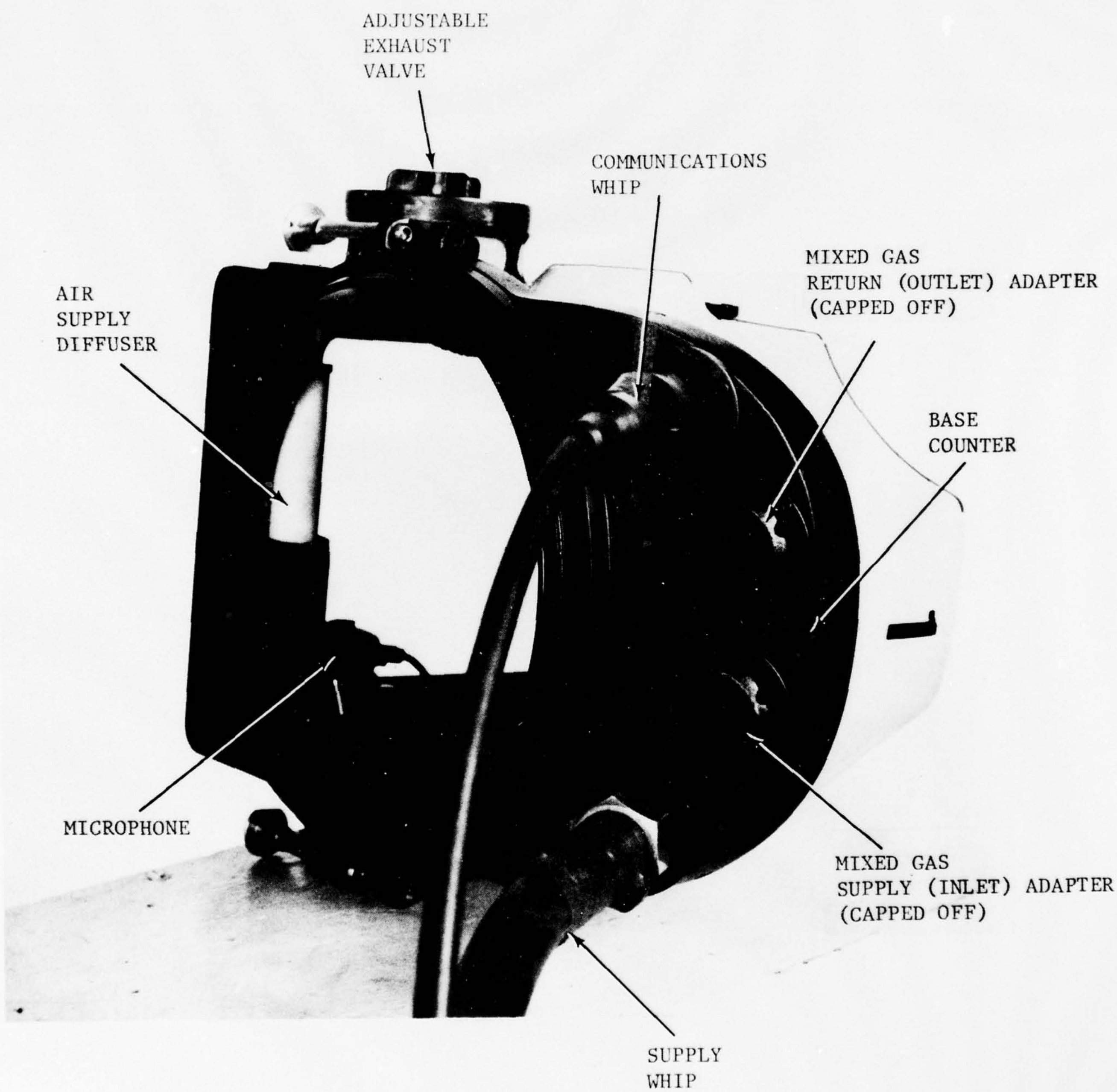

Figure 4. MK 12 SSDS helmet (bottom view)

1.3.1.1 Supply Valve. The supply valve is on the forward, right-hand side of the helmet. The valve is intended for use only in the emergency mode, but is often used in hose purging and for ventilating the diver during O_2 shift. The helmet air supply assembly needs no modification for use in the emergency mixed-gas mode or ventilating.

1.3.1.2 Exhaust Valve. The exhaust valve is located on the forward, left-hand side of the helmet. This valve is used only in the adjustable configuration for mixed-gas operations. It provides a variable helmet differential pressure (ΔP) range of 0.3 psig through 2.0 psig. The exhaust valve is adjusted by the diver for buoyancy and preferred ΔP. During O_2 flushing, the exhaust valve is opened and chin button is depressed in conjunction with the opening of the supply valve.

1.3.1.3 Helmet Communications. Helmet communications include a noise-canceling microphone and two transceiver earphones. A flexible chafing tube protects the microphone cable and earphone wiring harnesses placed between the helmet shell and sound-deadening polyurethane foam liner. The harnesses have snap pins on the microphone and earphone ends but are soldered to the external communications whip assembly inside the helmet. Thus, the communications whip assembly is not removed from the helmet for storage. A pre-amplifier is installed in the microphone cable when the MK 12 communications station is used in place of the Helle station. The communication assembly configuration is the same both for air and mixed-gas diving operations.

1.3.1.4 Mixed-Gas Adapters and One-Way Valves. Two mixed-gas adapters are located on the rear counter (plate) of the helmet base between the air adapter on the right and the communications whip on the left. To the left of center is the outlet (or return) adapter. Special one-way (Koegel) valves are fitted inside the mixed-gas adapters to prevent flow reversal in the recirculator. These one-way valves are always used in mixed-gas operations; during air operations, they are removed and the adapters capped. Inside the helmet, the mixed-gas adapters are connected to the mixed-gas supply and return ducting. The supply ducting directs the gas flow down across the front viewport and diver's face. Used gas is picked up by exhaust ducts near the helmet back, passed through the Koegel valve in the adapter, and is pulled into the recirculator through the recirculator return hose.

1.3.1.5 Helmet Breech Ring. The helmet breech ring is on the bottom of the helmet base. When the helmet breech ring is mated to the lower breech ring of the dress assembly, a dry diver envelope is provided. The two breech rings are O-ring sealed and locked into place by quick-release pins on both sides of the helmet. The configuration and operation are the same for both the mixed-gas or air configuration.

1.3.2 Dress Assembly

The dress (figure 1) used in mixed-gas operations is basically the MK 12 air issue. The neckdam configuration used for air swimming operations is not used in mixed-gas diving. (At present, the air jocking harness is not fitted with special D-rings for attaching the recirculator, but a harness design has been completed for mixed-gas use.) The drysuit, outer garment, weights, boots, and optional gloves are the same in both operations and are discussed in general below.

1.3.2.1 Drysuit. The drysuit is a commercially available drysuit modified in the neck area to accommodate the MK 12 lower breech ring assembly. It is made of 1/4-inch closed-cell neoprene rubber, backed on both sides with nylon fabric. The zipper across the diver's shoulders simplifies donning and doffing.

1.3.2.2 Outer Garment. The outer garment is blue, medium weight nylon with yellow seam stripes on the outside arms and legs for good underwater definition. The main purposes of the outer garment are to protect the drysuit, hold diver weights, and hold the jocking harness shoulder straps in place.

A special tubed outer garment is available for diving in water temperatures less than 50° F. Hot water from the surface is supplied to the outer garment and recirculator via a hot water hose that is married to the umbilical.

1.3.2.3 Jocking Harness. The adjustable jocking harness secures the helmet assembly to the diver, provides an attachment point for the umbilical, and serves as a further restraint against inadvertent overinflation of the drysuit.

1.3.2.4 Weights. The outer garment has three sets of pockets for accommodating 60 pounds of lead weights. The calf and thigh weights are required equipment and include three 4-pound thigh weights and four 2-pound calf weights for each leg. Two 5-pound hip weights per side may be added if additional weight is required and are considered task dependent. An optional SCUBA weight belt may be used during extreme tide or sea conditions but is not a MK 12 issue item.

1.3.2.5 Boots. The boots are lightweight rubber with a protective steel toe, weighted heels, and corrugated rubber soles. The boots are held in place with straps across the boot tops using loops and quick-release self-locking buckles. Rear boot loops connect to straps from the outer garment to further ensure against boot loss.

1.3.2.6 Gloves. The gloves are a trigger-finger mitten design. They are made of 1/4-inch thick laminated chloroprene foam material with cemented seams and outside reinforcements. Gloves are available in three sizes (small, medium, and large) and are considered task dependent.

1.3.3 Recirculator Assembly

Four operating configurations are available with the MK 12 SSDS mixed-gas recirculator (figures 5 and 6). In order of use preference, they are: umbilical supply, semiclosed circuit; umbilical supply, open circuit; emergency supply, semiclosed circuit; and emergency supply, open circuit.

During normal (umbilical, semiclosed) operations surface supplied gas enters the recirculator low-pressure manifold and passes through the ejector nozzle. As this gas passes through the ejector throat it creates a venturi effect which draws the gas to be recirculated through the canister where it is scrubbed of carbon dioxide. This mixture of surface supplied and scrubbed gas enters the helmet through the supply (inlet) hose and mixed-gas one-way

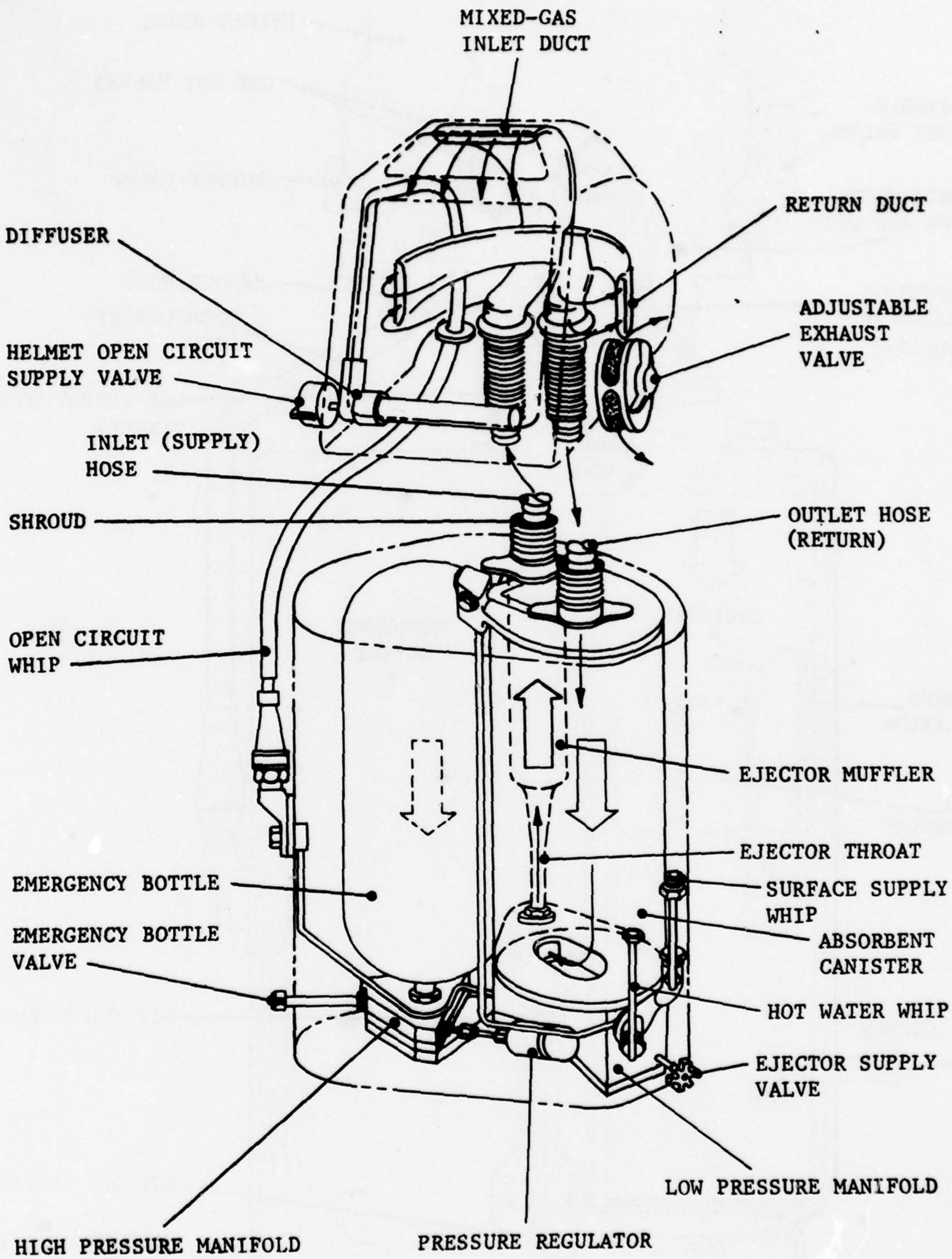

Figure 5. Recirculator and helmet flow, semiclosed.

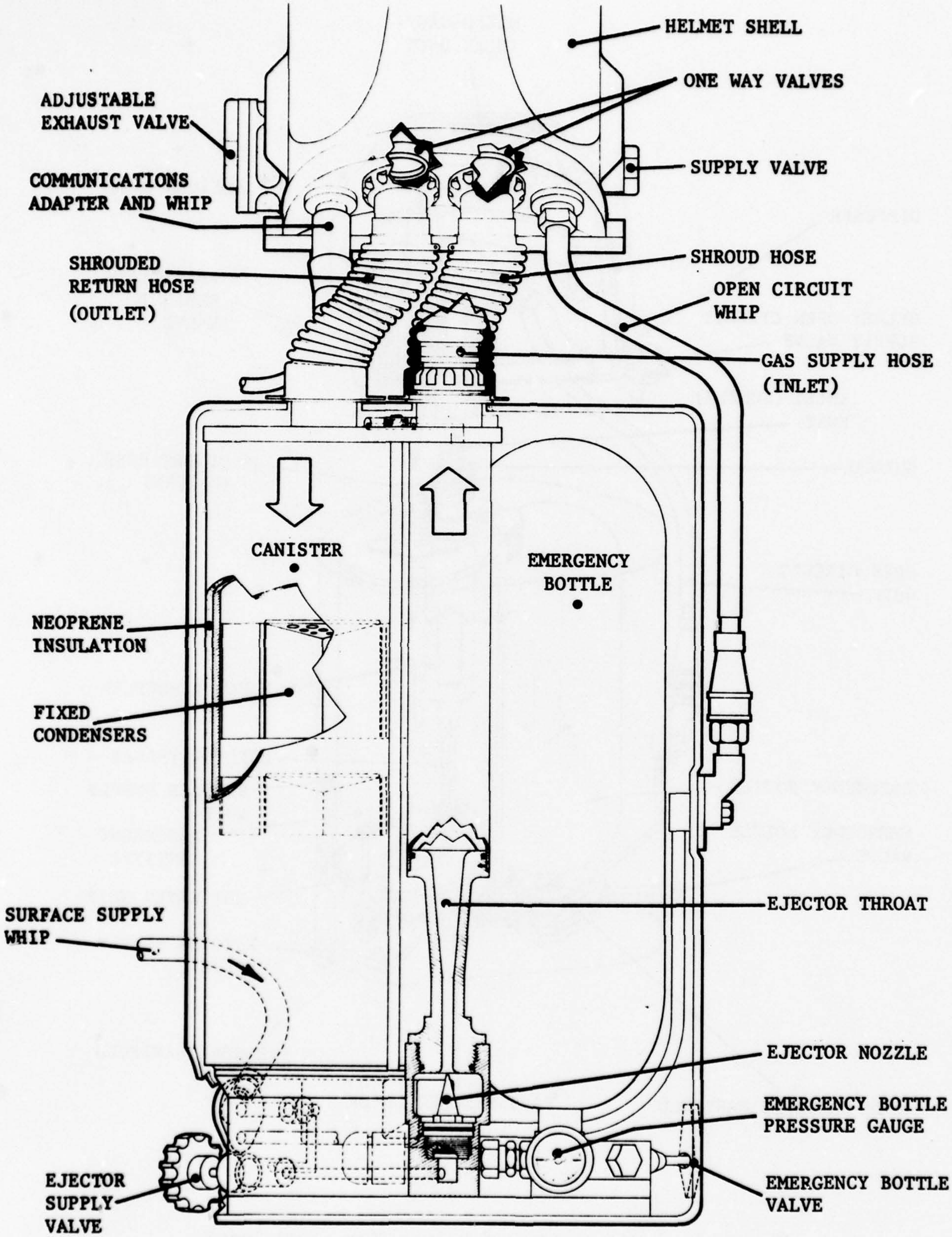

Figure 6. Recirculator assembly with helmet interface (rear view).

valve. While approximately 10% of the gas in the helmet is exhausted through the adjustable exhaust valve, 90% is pulled into the canister via the return (outlet) hose to complete the recirculation circuit.

Umbilical supply, open circuit, is used in the event of a recirculator failure when surface supplied gas can be fed directly to the helmet bypassing the recirculator. This configuration is also used when ventilating the diver on O_2.

The two mixed-gas emergency configurations use the emergency bottle located in the recirculator. Emergency, semiclosed circuit, is utilized when surface supplied gas is lost or becomes contaminated and the recirculator remains operational. Emergency, open circuit, is used if the surface supplied gas is lost and the recirculator fails. High-pressure mixed-gas from the emergency bottle is regulated at 30 psig overbottom pressure and is fed through a bypass whip to the helmet.

1.3.4 Support Equipment

All support equipment used with air operations, except for the flowmeter, is applicable to mixed-gas operations. Additional equipment related to mixed-gas operations consists of the following (one each):

Hot water source and hose (cold water operations only)
Recirculator spare parts kit and tools
Shipping case
Pressure reducer test assembly

1.4 PHYSICAL CHARACTERISTICS

1.4.1 Buoyancy

When manned, the system is neutrally buoyant with minimum weight addition under normal operating conditions. The system is capable of diver buoyancy control, both positive and negative.

1.4.2 Weight

System weight will vary from 107 to 127 pounds on the surface in the air configuration, and from 184 to 204 pounds when fully loaded in the mixed-gas configuration. (The 20-pound range is due to use of optional weights.)

1.4.3 Envelope Dimensions

When fully dressed, the diver will be able to pass through submarine and dive system hatches or climb unassisted through a cylindrical trunk 30 inches deep and 24 inches in diameter.

1.4.4 Canister Capacity

The standard canister holds 12 pounds of High Performance Sodasorb.

1.4.5 Emergency Bottle Capacity

The emergency bottle holds approximately 27.7 cubic feet of mixed gas at 2250 psig at standard temperature and pressure (STP).

1.5 PREVIOUS DEFICIENCIES

The original prototype recirculator was tested in 1973; the basic design and theory were proven valid, and venturi efficiency exceeded previous estimates. Numerous mission aborts were encountered primarily due to water leaks in the canister. The deficiencies noted below prompted initiation of a major redesign effort.

(a) Failure of canister cover, seals
(b) Inadequate piping for gas flow parameters
(c) Poor location of control knobs
(d) Cumbersome overall configuration

The NCSL recirculator basic design was developed during 1974 and 1975. Testing commenced in October 1975. At the end of the test series, a detailed review of the recirculator design found the following deficiencies.

(a) Canister duration times were inconsistent
(b) Canister seals leaked
(c) System flow rate and flow efficiency did not meet design requirements
(d) Ejector required a higher than normal driving pressure
(e) Mixed-gas ducting tended to collapse when subjected to maximum flow
(f) The interaction of one-way valves and recirculator hoses reduced gas flow below acceptable limits
(g) Gas flow channeling in canister

1.6 CORRECTIVE ACTION

All the above-mentioned items have been corrected.

1.7 SUMMARY

The MK 12 SSDS mixed-gas configuration was developed to replace MK V hard hat diving equipment. In general, the mixed-gas design offers the following improvements over the standard MK V MOD 1.

(a) General

(1) Increased diver safety
(2) State-of-the-art materials and production techniques
(3) Interchangeability of parts
(4) Improved overall system weight selectivity
(5) Reduced repair time

(b) Helmet Assembly

(1) Acoustic noise reduction
(2) Reduced CO_2 buildup
(3) Positive and negative buoyancy control
(4) Improved ventilation

(c) Dress Assembly

(1) Provision of a dry diver envelope
(2) Improved diver weight distribution
(3) Reduced possibility of diver blowup
(4) Improved diver mobility
(5) Improved diver comfort

(d) Support Equipment

(1) Test set
(2) Tools
(3) Spare parts
(4) Welding shield

(e) Recirculator Assembly

(1) Improved efficiency
(2) Lightweight construction
(3) Human engineering improvements
(4) Extended canister duration
(5) Improved insulation
(6) Gas heating capability

SECTION 2

UNMANNED TESTING

2.1 GENERAL

The unmanned test series demonstrated whether MK 12 SSDS physical characteristics meet required operational characteristics for a mixed-gas surface supported diving system (SSDS).

2.1.1 Location

These tests were conducted in the NCSC Hydrospace Laboratory (Building 108), Panama City, Florida, from February 1977 to October 1978.

2.1.2 Personnel

Tests were performed by Hydrospace Laboratory personnel assisted by MK 12 project personnel.

2.2 SCOPE OF TESTING

2.2.1 Conduct

This test series was conducted in accordance with table B-3 of the MK 12 TECHEVAL TEST PLAN, Project Number 131-1-DT-111G (reference 20).

2.2.2 Specific Tests

Using the final configuration of the MK 12 SSDS recirculator and helmet, test parameters comprised the following elements during unmanned testing.

2.2.2.1 Flow

(a) Confirm 6-ACFM mixed-gas flow at all depths to 380 FSW.
(b) Determine console pressures required to maintain 6 ACFM at all depths to 380 FSW.

2.2.2.2 ΔP (Differential Pressure) Hose Drop. Determine umbilical hose ΔP for 200, 400, and 600-foot lengths for both semiclosed and open circuit.

2.2.2.3 Ventilation. Verify surface equivalent CO_2 level in the helmet is less than 2% at selected depths to 380-FSW maximum.

2.2.2.4 Noise Level

(a) Confirm system noise levels at all depths to 450-FSW maximum meet current noise level standard (less than 90 dBA).

(b) Obtain noise level data in several frequency bands at selected depths to 450-FSW maximum.

2.2.2.5 Emergency Bottle Duration

(a) Determine emergency bottle time duration at various depths with 4-ACFM flow and semiclosed operation.

(b) Determine emergency bottle time duration at various depths with 4-ACFM flow and open circuit operation.

2.2.2.6 Overbottom Pressures for Semiclosed Circuit, Air and O_2. Determine overbottom pressures required to maintain 6-ACFM flow while operating with air or O_2.

2.2.2.7 Overbottom Pressures for Open Circuit, Air and HeO_2. Determine overbottom pressures required to maintain 6-ACFM flow while operating with air or HeO_2.

2.2.2.8 Open-Circuit O_2 Flushing at 40 FSW and 50 FSW. Determine time required to flush 600-foot umbilical at 40 FSW and 50 FSW.

2.3 RESULTS

2.3.1 Flow

(a) Flow of 6 ACFM was obtained at all operating depths to 380 FSW (reference 10).

(b) Flow tabulations are shown in figure 7, and table 1.

2.3.2 ΔP (Differential Pressure) Hose Drop

(a) Refer to table 2 for umbilical hose pressure drop, semiclosed circuit (references 11 and 13).

(b) Refer to table 3 for umbilical hose pressure drop, open circuit.

2.3.3 Ventilation

Graded exercises performed during NEDU manned dives produced data confirming a 6-ACFM flow provides adequate ventilation to hold the CO_2 level in the helmet well below 2% SEV. Unmanned testing of the CO_2 level was determined unnecessary due to the successful manned test results (references 3, 7 and 17).

2.3.4 Noise Level

Table 4 shows mixed-gas helmet noise level test results. The highest noise levels recorded were in the 31.5-dBA and 63-dBA bands. This is attributed to water burble in the test chamber. Average noise levels at significant depths (surface, 200 feet, and 450 feet) were notably lower than specification requirements. The highest spectrum average, 80.55 dBA, occurred at a depth of 200 feet (reference 21).

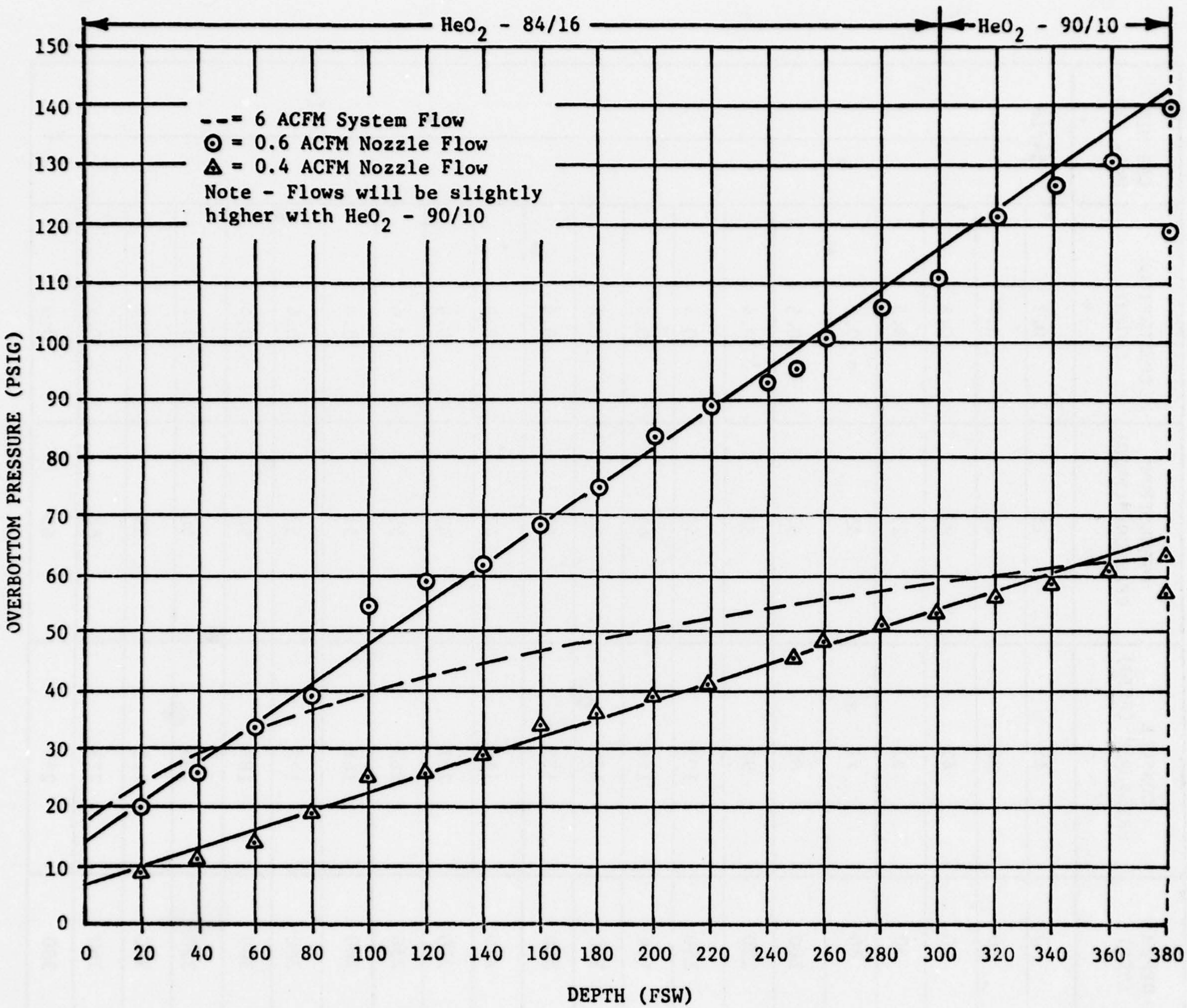

Figure 7. MK 12 SSDS mixed-gas flows, semiclosed circuit.

TABLE 1. MIXED GAS FLOW PARAMETERS, SEMICLOSED CIRCUIT

DEPTH (FSW)	CONSOLE PRESSURE* (PSIG)	OVERBOTTOM PRESSURE*(PSIG)	CONSUMPTION (ACFM)	GAS MIX HeO_2 (%)
0	19	18	0.7	84/16
20	32	21	0.7	
40	42	23	0.6	
60	57	29	0.5	
80	71	35	0.5	
100	82	37	0.5	
120	92	38	0.4	
140	103	40	0.4	
160	116	44	0.4	
180	125	44	0.4	
200	135	45	0.4	
220	146	47	0.4	
240	157	49	0.4	
250	162	50	0.4	
260	168	51	0.4	
280	177	52	0.4	
300	188	54	0.4	
320	199	56	0.4	
340	211	59	0.4	
360	223	62	0.4	
380	235	65	0.4	

* For 6 ACFM System Flow round off all pressures to the next higher number.

TABLE 2. SWAN UMBILICAL HOSE PRESSURE DROP (ΔP PSIG), SEMICLOSED

HOSE LENGTH	DEPTH (FSW)					
	0	200	300	380	400	450
200 FT	.07	.08	.09	.10	.10	.10
400 FT	.14	.20	.22	.22	.22	.22
600 FT	.23	.34	.35	.36	.35	.37

TABLE 3. SWAN UMBILICAL HOSE PRESSURE DROP (ΔP PSIG), OPEN CIRCUIT (600-FOOT HOSE ONLY)

DEPTH (FSW)	HeO_2 84/16	HeO_2 95/5
0	7.1	
100	18.7	
200	28.0	
300	36.4	29.7
380		28.3
400		34.0
450		33.5

TABLE 4. MK 12 SSDS HELMET NOISE LEVELS, SEMICLOSED CIRCUIT

NOZZLE FLOW	MANI-FOLD PRESS-URE	DEPTH (FSW)	SOUND PRESSURE LEVEL dB REF. .0002 DYNE/CM^2											% HeO_2 Gas Mix
			BROAD BAND (LIN)	BROAD BAND (A)	OCTAVE BANDS									
					31.5	63	125	250	500	1K	2K	4K	8K	
0.8	25	0	102	75	100	102	95	81	72	61	54	49	46	84/16
0.53	30	50	110	74	100	104	95	83	72	64	55	52	51	84/16
0.50	40	100	114	74	109	105	94	80	78	64	49	45	42	84/16
0.44	45	150	120	76	111	105	97	78	70	61	50	46	42	84/16
0.41	50	200	125	82	112	112	106	93	82	71	58	49	42	84/16
0.38	55	250	* 99	73	95	95	89	79	60	59	55	57	51	84/16
0.37	60	300	103	75	101	95	90	79	60	59	55	60	62	84/16
0.39	65	350	102	77	100	95	92	81	62	59	53	61	52	95/5
0.37	65	400	114	78	109	103	97	85	72	63	54	59	51	94/5
0.36	65	450	100	76	94	92	90	79	59	55	52	59	52	95/5

* Erratic microphone and sound level meter operation at depths of 250 ft. and greater.

2.3.5 Emergency Bottle Duration

The unmanned emergency bottle duration tests were inconclusive (reference 22); however, during the June-July 1978 manned testing, emergency bottle duration was checked with the diver at 380 FSW. These tests resulted in duration periods of seven and eight minutes before emergency bottle flow stopped and CO_2 exceeded 2% SEV in the helmet. At that time normal gas flow was resumed. Unmanned emergency bottle duration testing is scheduled to be repeated prior to OPEVAL.

2.3.6 Console Pressure Requirements

Refer to figures 8 and 9 (see references 10, 11 and 17).

2.3.7 Overbottom Pressures for Semiclosed Circuit, Air and O_2

Refer to table 5.

2.3.8 Overbottom Pressures for Open Circuit, Air and HeO_2

Refer to tables 6 and 7.

2.3.9 Open-Circuit O_2 Flushing at 40 FSW and 50 FSW

(a) A 600-foot umbilical requires 15 seconds to flush.
(b) System flushing to 80% with a 6-ACFM flow can be accomplished within 30 seconds; to 95%, within 90 seconds. Refer to table 8.

2.4 SUMMARY

The MK 12 SSDS mixed-gas operation meets all required physical standards.

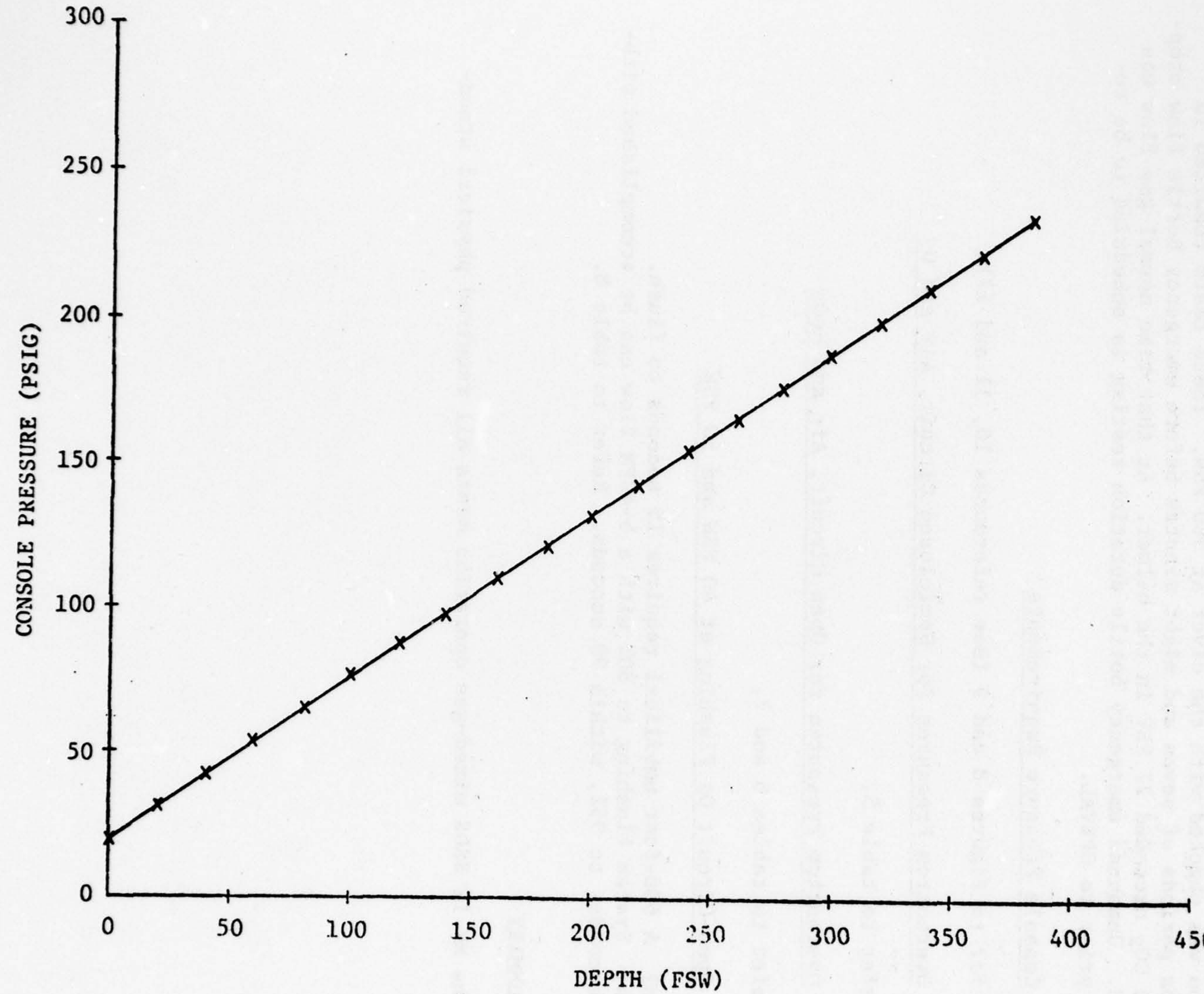

Figure 8. Console pressure requirements for semiclosed circuit umbilical supply at 6 ACFM

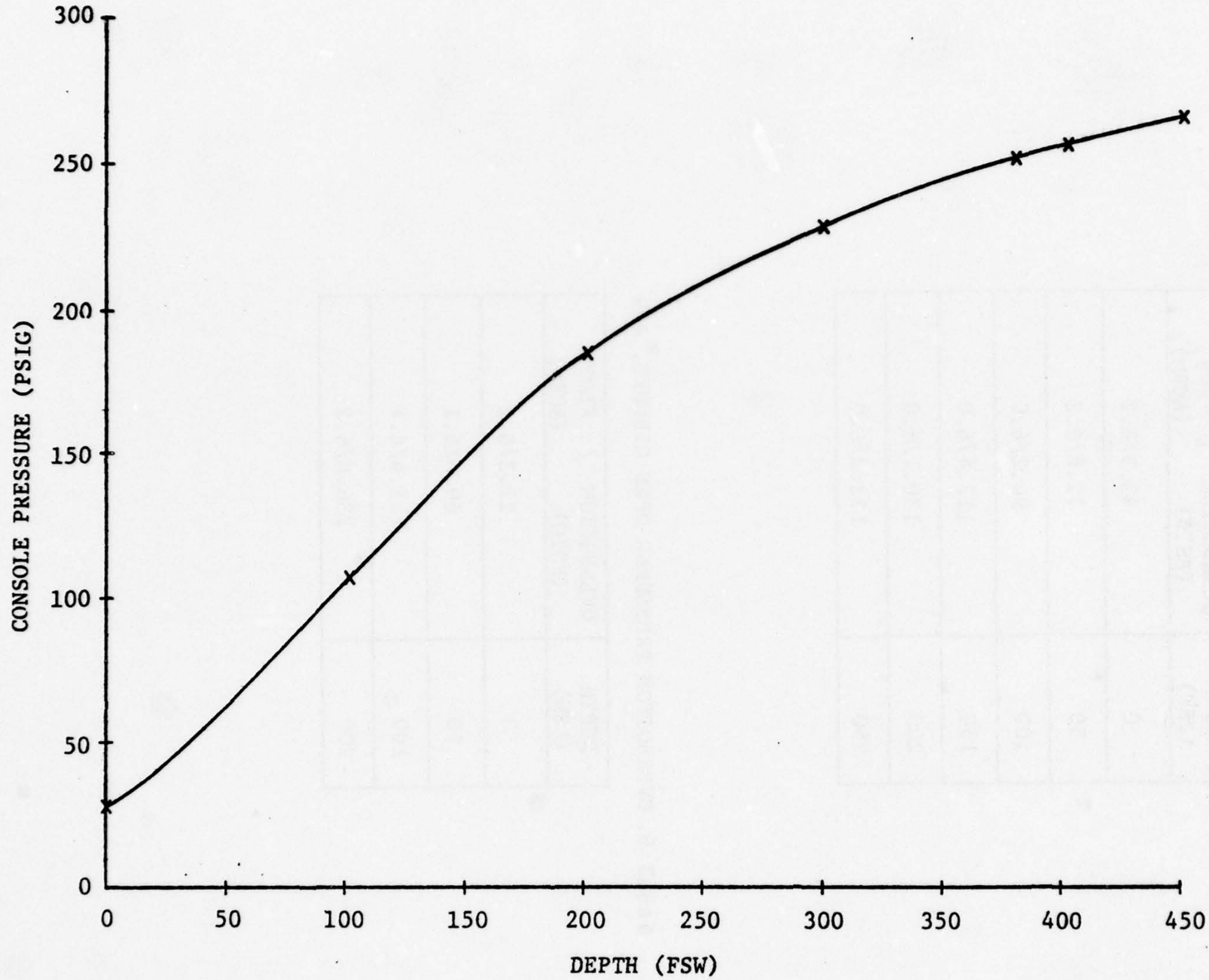

Figure 9. Console pressure requirements for open-circuit umbilical supply at 6 ACFM.

TABLE 5. OVERBOTTOM PRESSURES FOR SEMICLOSED CIRCUIT, AIR AND O_2

DEPTH (FSW)	OVERBOTTOM (PSIG) / FLOW (ACFM)
0	43.5/6.2
50	72.8/6.2
100	96.2/6.0
150	112.4/6.0
200	130.1/6.0
250	133.2/6.0

TABLE 6. OVERBOTTOM PRESSURES OPEN CIRCUIT, AIR

DEPTH (FSW)	OVERBOTTOM (PSIG) / FLOW (ACFM)
0	22.3/6.2
50	69.6/6.1
100	115.4/6.1
200	236.8/6.2

TABLE 7. OVERBOTTOM PRESSURES OPEN CIRCUIT, HeO_2

DEPTH (FSW)	OVERBOTTOM (PSIG) / FLOW (ACFM)
HeO_2 84/16	
0	20.5/6.0
100	88.6/6.1
200	157.5/6.2
300	204.7/6.3
HeO_2 95/5	
300	200.8/6.5
380	218.2/6.0
400	221.1/5.6
450	225.5/6.6

TABLE 8. OPEN CIRCUIT FLUSHING*, O_2

DEPTH FSW	FLOW ACFM	PERCENT OF FLUSHING 8%	80%	95%
50	8.0	12	25	67
	3.9	19	37	72
	6.7	13	29	73
	10.9	11	24	59
40	11.8	11	24	61
	9.3	13	24	63
	6.6	14	29	71
	4.3	18	41	78

* Percent O_2 versus time (in seconds).

SECTION 3

DEVELOPMENTAL TESTING

3.1 GENERAL

3.1.1 Scope

This section covers the research and development tests that established the physical and technical parameters of the MK 12 mixed-gas configuration.

Manned testing of the mixed-gas configuration had the following objectives: (1) to determine manned canister duration at several critical temperatures, (2) to evaluate system performance at limits of the required operational temperature range (29° F to 93° F), (3) to determine feasibility and effectiveness of incorporating a breathing gas heater, (4) to verify system flow is unaffected by the breathing gas heater, (5) to verify the system, as built, meets size specifications, and (6) to evaluate human factors using the recirculator system (see reference 18).

3.1.2 Location

A dive series was conducted in the 15-foot test pool at NCSC Building 319, Panama City, Florida, from 19 January 1978 to 14 February 1978. Extreme temperature limits were tested in the NCSC Hydrospace Laboratory test pool at 8 FSW on 15 and 16 February 1978.

3.2 DURATION TESTING

3.2.1 Objectives

Test objectives were to demonstrate and record MK 12 SSDS mixed-gas performance as designed and modified, with and without hot water gas heating.

3.2.2 Duration Test Limits

Duration test limits were: (1) a CO_2 buildup of 0.5% SEV measured at the recirculator outlet or (2) a nine-hour canister duration. Daily dives were terminated upon reaching either of these limits.

3.2.3 Procedures

Test parameters varied as follows:

(a) Bottom times were increased or decreased according to diver ability and stamina.

(b) Pool temperature was increased or decreased according to the configuration being tested.

(c) Each diver performed a ten-minute work cycle using the pedal ergometer at 50 watts for six minutes followed by a four-minute rest. The diver repeated this cycle for the dive duration.

(d) Dives were performed using various hot water heating configurations and commercial gas heating devices.

(e) Two different size absorbent canisters (nine-pound capacity and 12-pound capacity) were evaluated.

(f) High Performance Sodasorb was the absorbent used for testing; Medical Grade Sodasorb and granular Baralyme were used in one test each. Sodasorb was evaluated both with and without gas heating.

(g) Using eight digital thermistors at different locations, recirculator and helmet temperatures were recorded every 15 minutes during the dive.

(h) CO_2 measurements were made and recorded at the recirculator outlet.

(i) The 600-foot umbilical was faked down in the bottom of the test pool to evaluate gas and water hose temperature loss.

(j) These dives were performed by seven U.S. Navy divers, a medical diving technician, a master diver, and a diving officer. Various divers from Fleet units received indoctrination and familiarization dives using the MK 12 air configuration and then acted as standby divers.

3.2.4 Results

During the early test dives, several different gas and canister heating techniques were tested. A nine-hour duration was first achieved on 26 January 1978. The test configuration used the large absorbent canister and a hot water heated canister top with shrouds made of drysuit material surrounding the inlet and outlet hoses. In subsequent duration dives, the canister top heater was a triangular-flanged plate channeled to exhaust hot water around the inlet and outlet ports of the canister top. This was used for testing at both lower and higher temperatures. Eight of eleven dives met or exceeded the nine-hour requirement (reference 18).

3.2.4.1 Medical Grade Sodasorb. All nine-hour duration dives, with one exception, were made using High Performance Sodasorb as a CO_2 absorbent; Medical Grade Sodasorb was used during one dive for comparison.

3.2.4.2 Heating. Heating the canister top and the recirculator case interior proved effective in ensuring the CO_2 absorbent chemical reaction continued for the dive duration.

3.2.4.3 Recirculator. In this test period, a single MK 12 SSDS recirculator made 88 dives for a total of 15.2 hours without an abort. In addition, the same equipment was used for ten brief training dives. Individual test dive durations ranged from one hour (in 29° F water without recirculator heating) to five hours (in 40° F water without diver heating).

3.2.4.4 Unscheduled Dive. Because of the excellent duration results at water temperatures between 35° and 40° F, an unscheduled duration dive in 29° F water was conducted on 16 February 1978. Duration of this dive was nine hours with no indication of canister CO_2 at dive completion. However, due to pool size and the effect of adding hot water for both recirculator and diver heating, the pool water temperature increased to 39° F.

3.2.5 Conclusions

The triangular-flanged plate configuration was adequate for the nine-hour duration. Warm water inside the case produced the proper recirculator conditions for desired CO_2 scrubbing action at the test temperatures. In addition, the shrouds of the inlet and outlet hoses and the large canister enhanced the efficiency of the mixed-gas configuration.

3.2.5.1 Modified Recirculator. The modified recirculator operated efficiently for the required nine-hour duration in water 50° F and above without hot water heating.

3.2.5.2 Absorbent. High Performance and Medical Grade Sodasorb provided longer canister durations than granular Baralyme under the same test conditions. Tests of Medical Grade Sodasorb and granular Baralyme are inconclusive, however, because only one test with each absorbent was conducted. Medical Grade Sodasorb has demonstrated a nine-hour canister duration capability in a water temperature of 50° F and should therefore be satisfactory for the MK 12 recirculator above this temperature. It may be concluded that Baralyme is suitable for use in the MK 12 recirculator for dives less than six hours in water temperatures 50° F or higher.

3.3 MANNED EXTREME TEMPERATURE TESTING

3.3.1 Objectives

These tests were performed to demonstrate that the MK 12 mixed-gas configuration would operate in water 29° to 93° F. Warm water (93° F) testing was cancelled because of the need to complete duration studies and lack of additional test time.

3.3.2 Procedures

Test procedures varied as follows.

(a) Due to diver availability, two divers (rather than one) were used.
(b) Diver heating was not used in this test.

3.3.3 Results

The recirculator operated satisfactorily without icing or malfunction.

3.3.4 Conclusions

The MK 12 SSDS mixed-gas recirculator design will operate in 29° F water without supplemental heating.

3.4 BREATHING GAS HEATER EVALUATION

3.4.1 Objectives

The objective of this test phase was to further evaluate gas heating as a means of extending canister duration in cold water (below 50° F) diving.

3.4.2 Procedures

A Kinergetics gas heater, HEX-5 Model 3330, was used for evaluation. The heater was inserted in place of the ejector muffler in two tests and on top of the canister cap for one test. In addition, the number of heating elements used in the heater on the canister cap was varied in two other tests.

3.4.3 Results

Using the gas heater in any of the configurations and in conjunction with the large canister did not yield the required nine-hour canister duration. When the gas heater was used, the temperature drop across the recirculator inlet and outlet hoses and the helmet resulted in previously heated gas reentering the canister at ambient temperature. When the gas heater was tested on top of the canister, the heated gas acted to dry out the absorbent bed and forced bed moisture through the ejector into the helmet. As the absorbent bed dried, canister efficiency was reduced. The use of hot water heating (versus gas heating) on the canister top and inside the recirculator case produced better duration results for MK 12 mixed gas (reference 18).

3.4.4 Conclusions

A standard gas heater does not produce the necessary conditions in the MK 12 to achieve required canister durations.

3.5 SYSTEM SIZE EVALUATION

3.5.1 Objectives

The MK 12 SSDS design requirements state that a diver must be able to pass through a 24-inch diameter opening, 30 inches deep. These dimensions represent a submarine hatch or watertight door scuttle. Verification was needed that the final mixed-gas equipment configuration met this requirement.

3.5.2 Procedures

A metal hatch mockup with an opening 24 inches in diameter and 30 inches long was fabricated and arranged in a vertical position at the ladder entering the test pool. At selected times during the dives, each diver was required to pass through the mockup to return to the surface. Photographic records were made as the test was conducted.

3.5.3 <u>Results</u>

All divers were able to pass through the hatch mockup, although the larger divers did so with moderate difficulty (reference 18).

3.5.4 <u>Conclusions</u>

The MK 12 mixed-gas equipment meets design size requirements.

3.6 HUMAN FACTORS EVALUATION

3.6.1 <u>Objectives</u>

The human factors evaluation addressed the following design aspects of the MK 12 SSDS recirculator:

(a) Adequacy of location, size, and accessibility of the two diver manipulated valves.
(b) Characteristics of the recirculator harness regarding reach envelopes, anthropometric factors, and comfort.

3.6.2 <u>Procedures</u>

3.6.2.1 <u>Supply and Emergency Control Valve Adequacy</u>. During this portion of the evaluation, divers were timed at opening and closing the emergency gas valve and the gas supply valve. Each diver was also asked to determine as quickly as possible the status (open or shut) of the various emergency valve configurations (including the ejector supply valve) when randomly preset.

3.6.2.2 <u>Anthropometric Adequacy</u>. A photographic comparison of the MK 12 air and mixed-gas configurations was made to determine effects of the recirculator backpack on five appropriate anthropometric positions: (1) shoulder joint flexion, (2) shoulder joint extension, (3) hip joint flexion, (4) hip joint extension, and (5) trunk flexion.

3.6.2.3 <u>Entanglement</u>. Deliberate attempts were made with a 5/8-inch line to entangle the diver and recirculator.

3.6.3 <u>Results</u>

3.6.3.1 <u>Valve Manipulation</u>. Average times for the diver to move the valves from fully open to closed were 4.66 seconds for supply and 1.72 seconds for emergency.

3.6.3.2 <u>Anthropometric Considerations</u>. An initial review of the photographic record indicates the recirculator causes minimal restriction to underwater movement (see reference 18).

3.6.3.3 <u>Entanglement</u>. All divers were able to free themselves from the entangling line at the supply valve or around the lower recirculator in five to 15 seconds. The only area which might pose an entanglement problem

would be the two exposed gas hoses which exit the recirculator top and enter the helmet back. Unlike the lower backpack, these upper hoses cannot be reached by the diver.

3.6.4 Conclusions

In its present configuration, the MK 12 recirculator and accompanying harness pose no significant human engineering problems.

Operation of the recirculator valves at the recorded speeds should be adequate for all anticipated operational and emergency conditions.

3.7 OTHER EQUIPMENT EVALUATIONS

During this test series, several additional MK 12 system equipment items were evaluated. Each item is addressed separately in the paragraphs which follow.

3.7.1 Knife and Diver Weight Belt

The COMOPTEVFOR MK 12 OPEVAL Report for air equipment recommended that a diver's knife and an additional weight belt be identified for the MK 12 system and that procedures for using these items be developed (reference 5).

Only knives and weight belts acceptable for U.S. Navy use were evaluated. This included seven knives and two weight belts. The knives were placed on the harness, the leg or the arm, according to diver preference. Divers preferred a knife having a sheath with a belt for wearing on the center harness strap; however, all knives tested were acceptable. Weight belts were worn both over and under the harness; the former option proved more comfortable and accessible.

3.7.2 Underwear

A first generation set of underwear was evaluated by several divers during duration dives. This garment was fabricated from a MK 12 developed material consisting of a fabric sandwich with a nylon exterior, a 1/4-inch polyester open-cell foam center, and a nonallergenic synthetic lining.

Results of the evaluation were inconclusive. However, the dress, as designed, was believed to be a slight improvement over other available items. Diver heat loss in cold water was not totally eliminated; therefore, to improve insulation, a thermal reflective material will be evaluated in the next version.

3.7.3 DUI Water Heater

A DUI Gulf hot water heater was tested because it can support deep diving and is typical of equipment used in commercial diving. A complete evaluation of the water heater was not attempted in this test series.

The water heater operated for approximately 139 hours with failures occurring at 70 and 126 hours. Repairs were made without major problems. Temperature and flow control were adequate although the water heater required constant attention during operation. The maintenance manual provided with the heater proved to be inadequate during repairs. Modifications to the heater and further testing will be recommended as a separate subject.

SECTION 4

MANNED TESTING

4.1 GENERAL

Manned TECHEVAL testing of the MK 12 SSDS began during a saturation dive at NEDU's Ocean Simulation Facility (OSF) on 29 June 1978 and was completed on 30 October 1978 aboard the YRST-1 at Pokai Bay, Oahu, Hawaii. The official design freeze of the MK 12 recirculator was on 6 February 1978; four production model recirculators were delivered to NEDU for evaluation in April 1978. In the research and development phase (see section 3), an extreme exposure depth limit of 450 FSW was established; however, canister durations did not meet the nine-hour operational requirement. For this reason TECHEVAL was divided into saturation and nonsaturation (reliability) phases, resulting in two areas of data analysis.

4.2 SATURATION DIVES

4.2.1 Background and Results

In February 1977, manned evaluations of the prototype MK 12 mixed-gas configuration were performed in the OSF. Saturation test results demonstrated the system can temporarily support a diver performing heavy work to 450 FSW. Mean canister duration for all depths was 79 minutes (see reference 7).

During the June-July 1978 TECHEVAL saturation dives at OSF (reference 19), the mixed-gas configuration was tested to 390 FSW while supporting a diver doing heavy work. The tests were concluded when the canister repeatedly reached the required nine-hour duration without a CO_2 breakthrough of 2% SEV at the helmet, as indicated in figure 10.

All saturation dives (including development tests of February and November 1977) were performed according to NEDU protocol; however, only the June-July 1978 tests provided data collection specified in the TECHEVAL Test Plan. Therefore, Reaction Time (T_R) or Turnaround Time (T_T) cannot be calculated from the data available. Test results that can be used for TECHEVAL are:

Number of dives	20
Total demand time	35 hours, 36 minutes
Number of aborts 1/	1
Total down time 2/	55 minutes

1/ The abort was due to the improper setting of a pressure regulator during predive checkout and was attributed to human error.

2/ Due to the confined quarters of the chamber and the presence of extensive medical testing equipment, the mean time to repair was much higher than it would be under normal nonsaturation conditions.

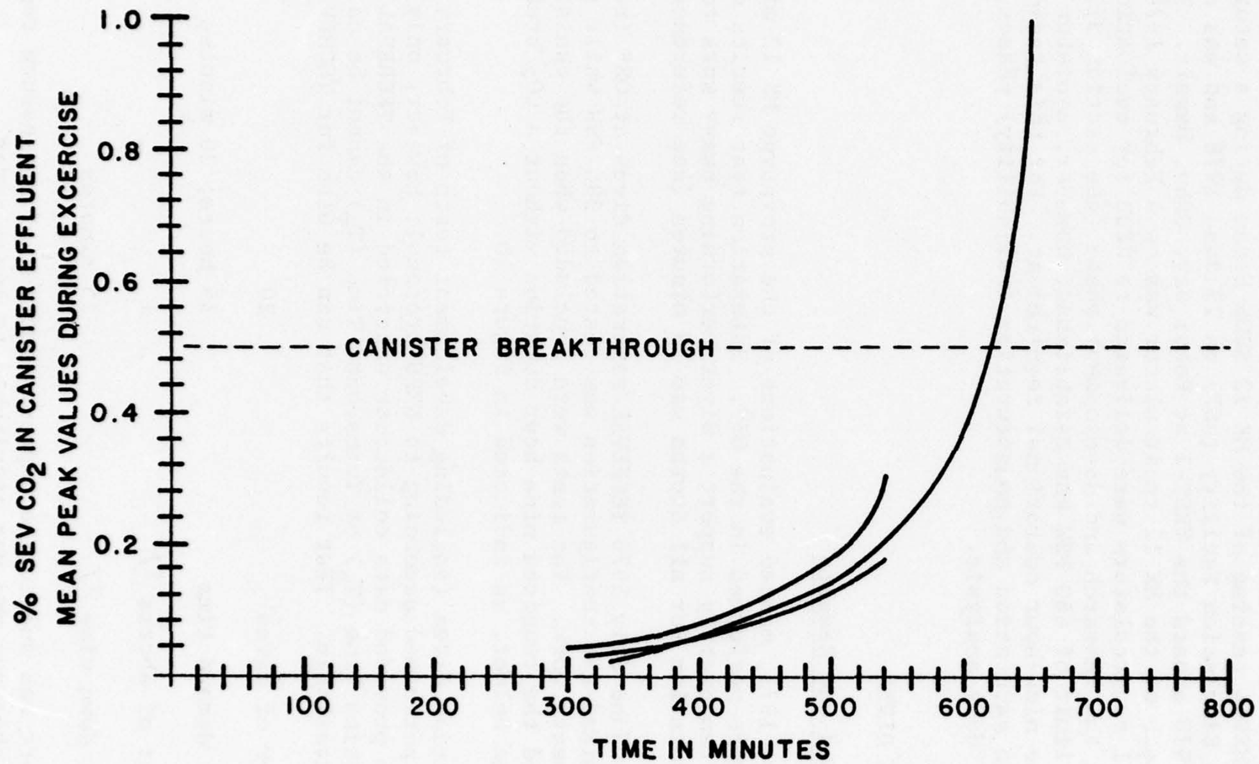

Figure 10. MK 12 canister breakthrough, 390 FSW.

4.3 NONSATURATION DIVES (RELIABILITY)

4.3.1 Background

MK 12 SSDS mixed-gas TECHEVAL was conducted from 27 September through 30 October 1978 at sea off Pokai Bay, Oahu, Hawaii, using the diving platform YRST-1 from Harbor Clearance Unit One (HCU-1). Twenty-four fleet divers from HCU-1, USS BEAUFORT (ATS-2), USS BRUNSWICK (ATS-3), and USS SAFEGUARD (ARS-25), plus instructor and project personnel from NSDS, NCSC, and NEDU, performed all TECHEVAL diving. A total of 271 mixed-gas dive missions were performed (218 at sea plus 53 training) with one abort. The one abort was due to a communication failure; no aborts were attributed to the life support equipment. The dive profiles accomplished were as follows:

120 dive missions at 100 FSW

50 dive missions at 200 FSW

24 dive missions at 250 FSW

24 dive missions at 300 FSW

TOTAL 218 dive missions

The tests to be conducted were divided into three categories: Technical (T Test), Materiel (M Test), and Human Factors (H Test).

4.3.2 Technical Effectiveness Test T-1

The purpose of test T-1 was to determine MK 12 SSDS technical effectiveness in supporting a working diver on mixed gas from the surface to 450 FSW. Due to the restrictions of nonsaturation diving, the system was tested to the Normal Working Dive Limit (NWDL) of 300 FSW. For purposes of TECHEVAL, major equipment failures were defined as failures causing an abort due to serious injury to divers or tenders, or reduction of the system's operational capability. All other failures were considered minor.

4.3.2.1 Data Analysis and Results

Number of dive missions	218
Average bottom time (calculated for nonsaturation dives only)	20 minutes
Number of aborts	1

4.3.2.2 Equipment Failures

(a) Major

Helmet Assembly	0
Dress Assembly	0
Recirculator Assembly	0
Support Equipment	0

(b) Minor

Helmet Assembly	1
Dress Assembly	0
Recirculator Assembly	0
Support Equipment	0

4.3.2.3 Reliability. Both Life Support Reliability (R_L) and Mission Reliability (R_M) were considered for the total system dives during TECHEVAL.

Design Standard	Reliability	Confidence	No. Dive Missions
R_L	0.975	95%	120 with no aborts
R_M	0.900	90%	120 with 7 aborts
TECHEVAL Performance			
R_L	0.986	95%	218 with no aborts
R_M	0.982	90%	218 with 1 abort

4.3.2.4 Turnaround Time (T_T). No attempt was made during diving operations to expedite turnaround time due to concurrent surface decompression operations. In all cases, the next diver was completely dressed and needed only to don the helmet and recirculator used in the previous dive to commence the next dive. With divers experienced in the use of the MK 12, turnaround time can be reduced to less than five minutes.

The T_T average (mean) for the total 218 dive missions includes down time and repair time.

T_T (mean) = 10.8 minutes
T_T (median) = 11.5 minutes
T_T (minimum) = 5.0 minutes

4.3.2.5 Reaction Time (T_R). The initial setup and predive checks were conducted slowly and thoroughly to instruct new personnel in the proper use of the MK 12 helmet test set. As TECHEVAL proceeded, the reaction times decreased with the following results:

T_R (mean) = 25.0 minutes
T_R (median) = 29.9 minutes
T_R (minimum) = 15.3 minutes

4.3.2.6 Surface Decompression (SUR D). Timed surface decompression procedures were exercised. Surface decompression reaction time was measured from the time the diver left the 40-FSW stop on O_2 until repressurization to 40 FSW in the chamber.

SUR D (mean)	= 3 minutes, 20 seconds
SUR D (median)	= 3 minutes, 10 seconds
SUR D (minimum)	= 2 minutes, 20 seconds

4.3.3 Materiel Suitability Tests M-1 through M-6

The purpose of this test series was to provide a comprehensive evaluation of MK 12 SSDS materiel effectiveness in an operational environment. This phase was measured in terms of Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Operational Availability (A_O), Logistic Support Index (LSI), and routine predive/postdive checkout times and Turnaround Time (T_R) per dive.

4.3.3.1 Test M-1, Reliability. These tests evaluated materiel reliability of the MK 12 SSDS recirculators. The Mean Time Between Failure (MTBF) for each MK 12 system used in TECHEVAL was computed using the total operating time divided by the total number of critical and major failures occuring during this period. The test results of the four prototype recirculators, tested after the design freeze, in the June-July 1978 saturation and the TECHEVAL nonsaturation test series are reported below:

(a) Saturation diving operational time/failures:

35.58 hours/none

(b) Nonsaturation diving operational time/failures:

Recirculator 1	68.26 hours/none
Recirculator 2	26.96 hours/none
Recirculator 3	70.00 hours/none
Recirculator 4	16.70 hours/none

(c) Training dives operational time/failures:

Recirculator 1 17.67 hours/none

Total TECHEVAL operational time/failures = 235.17 hours/none

MTBF at 90% confidence = 108.6 hours

For the purpose of this test (M-1), all research and development testing before the design freeze will be considered in calculating the recirculator MTBF.

(d) RDT&E operational time/failures:

585.3 hours/none

(e)	TECHEVAL	235.17 hours
	RDT&E	585.30 hours
	Total	*820.47 hours*

(f) Number of failures = none

Therefore, the overall MTBF at 90% confidence is the total operating time divided by the number of failures.

$$\text{MTBF} = \frac{820.47}{\text{none}} \text{ hours}$$

MTBF at 90% confidence is 359.7 hours with a failure rate of .00278

4.3.3.2 Test M-2, Maintainability. The purpose of this test was to evaluate MK 12 materiel maintainability. The evaluation showed:

(a) The test set, tools, and spare parts provided were adequate.
(b) No maintenance safety hazards were encountered.
(c) Upon receipt, the equipment was in excellent condition.
(d) Approximately 30 minutes per day for 23 days, a total of 11.5 man-hours, were required to maintain the MK 12 system during TECHEVAL.
(e) No special tools or materiel were required.
(f) The condition of spare parts on receipt was excellent.
(g) The ability of technicians with formal maintenance training was excellent; no required repairs were beyond the capabilities of assigned personnel.
(h) The location and function of electrical and mechanical safety devices were adequate.
(i) There were no difficulties in making or maintaining system adjustment.

There were no critical life support equipment failures during TECHEVAL. The only abort was due to a broken wire in the communications whip. The communications whip is permanently soldered to the helmet communications assembly (earphones and microphone) and is not removed for storage. (Its design precludes faulty connections that cannot be repaired topside during the dive operation.) Stress at the recirculator shroud/helmet communications whip interface flexed the whip beyond the internal connectors' elastic limits, resulting in failure. The probable cause for failure was improper handling during turnaround procedures. During repair, a failed O-ring on the umbilical end was identified; the resulting leakage may have contributed to whip failure. The Mean Time To Repair (MTTR) for this failure, including a 15-minute Mean Time For Fault Location (MTFL), was 45 minutes.

The helmet shell communications adapter has been redesigned to eliminate the stress area. Proper handling precautions are being incorporated in the Operations and Maintenance (O&M) Manual (NAVSEA 0994-LP-018-5010).

Total checkout time, predive and postdive, was 19 hours and 53 minutes for the 23 days of nonsaturation diving. Total checkout time between dives was 6.8 minutes. Mean checkout time per diving day was 50.3 minutes.

4.3.3.3 Test M-3, Operational Availability (A_O). Test M-3 was conducted to determine the probability that the MK 12 SSDS will be operationally ready, when needed, at any point in time.

Operational availability is computed using demand usage time divided by demand usage time plus downtime. Demand usage time is the time during which the equipment can be operated to minimum specified standards. Downtime is the total time resulting from all maintenance and administrative actions plus logistic maintenance delays.

<u>Standard</u>	<u>TECHEVAL Results</u>
A_O = 0.75 with a 90% confidence	$A_O = \frac{235.17}{236.74} = 0.993$
	A_O = 0.894 with a 90% confidence

4.3.3.4 <u>Test M-4, Compatibility</u>. The purpose of this test was to determine the compatibility of the MK 12 with support equipment and the operational environment.

During TECHEVAL there were no shock or vibration effects detected on the MK 12 SSDS.

There were no abnormal operations or casualties experienced during TECHEVAL due to test associated damage, misalignment or the environmental conditions.

4.3.3.5 <u>Test M-5, Supportability</u>. This test assessed MK 12 supportability in the operational environment by evaluating the logistic support available and exhibited during TECHEVAL.

No logistic support deficiencies were reported during TECHEVAL. There were adequate spare parts on board, the method of equipment support was adequate, and equipment support information was adequate. The logistic support index (LSI), which is determined by dividing the total supply downtime by the number of critical or major failures experienced, could not be calculated because there were no failures. Logistic support of the project was excellent.

4.3.3.6 <u>Test M-6, Technical Documentation</u>. Test M-6 objectives were to evaluate the Operations and Maintenance Manual (NAVSEA 0994-LP-018-5010) and other printed operational and maintenance aids, including routine maintenance checkoff sheets.

Analysis of TECHEVAL Test Plan data sheet No. 4 indicates the O&M manual requires some modification to reflect changes in procedures, system design, and associated equipment. In general, however, the manual was complete and useful for MK 12 operational maintenance.

According to MK 12 divers, the manual was easy to read and understand. Most divers, however, said they needed more time to adequately assess the manual. The younger, less experienced divers relied more on the manual than other divers. Formal MK 12 training is required prior to actual use of the system.

The system checks, tests, and procedures were considered adequate, except technicians required a more detailed schematic diagram of the communications assembly. This has been completed and included in the manual.

In general, the O&M manual was considered complete as provided. Several divers suggested the O&M manual be more concise and materiel descriptions were, in places, redundant. Documentation was received in time to be of value as a maintenance aid.

4.3.4 Human Factors Tests H-1 and H-2

Two human factors tests assessed MK 12 SSDS capabilities for service use from a personnel standpoint, the quality of personnel operations and maintenance training, and existence of potential safety hazards.

4.3.4.1 Test H-1, Human Engineering. Human engineering test objectives were to determine MK 12 capabilities to provide an effective, safe working environment with minimum discomfort, distraction and chance for error. Questionnaires were compiled by Fleet divers after MK 12 diving was concluded. Diver comments are summarized and evaluated in Appendix A.

Overall acceptance of MK 12 was enthusiastic. During debriefing, when given the choice between existing fleet diving equipment and the MK 12, first and second class Fleet divers were unanimous in their choice of the MK 12 for any underwater task.

The majority of divers and tenders found operational design of the helmet, dress, recirculator, and mixed-gas assemblies satisfactory. Over 90% of the divers and tenders considered predive, turnaround, canister cleaning and filling, postdive, surface decompression, normal operating and emergency procedures adequate. Reference Appendix A for a comprehensive summary of divers' and tenders' evaluations.

4.3.4.2 Test H-2, Personnel and Training Requirements. Test H-2 determined the quality of the divers' training as operators and technicians for the MK 12. See Appendix A for results of operations and maintenance training assessment questionnaires.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

The TECHEVAL of the MK 12 SSDS mixed-gas portion of the system was completed in a satisfactory manner. While requirements for several minor equipment modifications became apparent during the course of the evaluation, all systems of the MK 12 functioned as designed. In addition, diver acceptance was positive and enthusiastic. Table 9 summarizes TECHEVAL results.

5.2 PHYSICAL CHARACTERISTICS

5.2.1 Buoyancy

5.2.1.1 Required. The system, when manned, is to be neutrally buoyant with minimum weight addition under normal operating conditions. Diver buoyancy control, both positive and negative, is required.

5.2.1.2 Actual. The MK 12 SSDS mixed-gas configuration was proven to be neutrally buoyant with weight variations determined by diver preference. All TECHEVAL divers were able to demonstrate buoyancy control, both positive and negative.

5.2.2 Weight

5.2.2.1 Required. The system normally will not weigh more than 190 pounds when fully loaded on the surface in the mixed-gas configuration.

5.2.2.2 Actual. The MK 12 mixed-gas configuration weighs 184 pounds when fully loaded on the surface. Additionally, there are 20 pounds of optional weights which are task dependent.

5.2.3 Envelope Dimensions

5.2.3.1 Required. The diver, when fully dressed, will be able to pass through submarine and dive system hatches and climb, unassisted, through a cylindrical trunk 30 inches deep and 24 inches in diameter.

5.2.3.2 Actual. This has been successfully demonstrated in the mixed-gas configuration.

5.3 REQUIRED MODIFICATIONS

The recommended system modifications which follow are the result of TECHEVAL.

5.3.1 Helmet Assembly

5.3.1.1 Communications Whip Cable Assembly. A strain was placed on the whip at the counter connector. Redesign has been completed to modify the adapter and whip.

5.3.1.2 Inlet and Outlet Mixed Gas. The one-way Koegel valves were inadvertently reversed; the adaptors are being modified to preclude valve reversal in the future.

5.3.2 Dress Assembly

5.3.2.1 Jocking Harness. The harness must be lengthened approximately six inches. The release mechanism requires stainless steel construction.

5.3.3 Recirculator

5.3.3.1 Backpack. Small cracks in the outer case prompted reinforcement modifications. Harness interface straps are being lengthened.

5.3.3.2 Emergency Bottle Valve. External protection is required to prevent accidental turning. A shield has been designed, and satisfactorily tested, that prevents accidental turning or damage.

5.4 CONCLUSION

Pending completion of the modifications noted above, the MK 12 SSDS is ready for OPEVAL in accordance with the MK 12 SSDS Test and Evaluation Master Plan (reference 23).

TABLE 9. OPERATIONAL AND TECHNICAL CHARACTERISTICS SUMMARY RESULTS

Operational Characteristics	MK 12 Objectives	TECHEVAL Results
Normal Working Depth Limit (NWDL)	300 FSW	300 FSW
Exceptional Exposure Depth Limit	380 FSW	380 FSW
Extreme Exposure Depth Limit	450 FSW	450 FSW
Total Time of Dive Limit	9 hours	9 hours 2/
Lower Temperature Limit	29° F	29° F
Higher Temperature Limit	93° F	93° F
Sea State 1/	4	4
Maximum Water Current 1/	2 knots	2 knots
Noise Level	<90 dBA	<90 dBA
Speech Intelligibility	85%	85%
CO_2 Ventilation, Surface Equivalent 3/	2% Maximum	1.6%
Flow Capability at All Depths	6 ACFM	6 ACFM

NOTE:

1/ Limited by sea conditions prevalent during the test period.
2/ At 300 and 390 FSW.
3/ At the helmet.

Technical Characteristics	MK 12 Developmental Objectives	TECHEVAL Results
Life Support Reliability (R_L)	≥0.975	0.986
Confidence	95%	95%
Mission Reliability (R_M)	≥0.90	0.982
Confidence	90%	90%
Operational Availability (A_O)	≥0.75	0.894
Confidence	90%	90%
Reaction Time (T_R)	<30 minutes	25 minutes
Turnaround Time (T_T)	<20 minutes	10.8 minutes
Mean Time to Repair (MTTR)	< 4 hours	45 minutes
Mean Time Between Failures (MTBF)	355 hours	359.7 hours

REFERENCES

1. Specific Operational Requirement 46-54, Surface Supported Diving System, September 17, 1970.

2. NEDU Interim Report 7-74, Technical Evaluation of the Modified Prototype Surface Supported Diving System, USN MARK XII, September 17, 1974.

3. NEDU Research Report 16-74, Determination of the Adequacy of Helmet Ventilation in a Prototype Navy MK XII and MK V Hard Hat Diving Apparatus, 16 July 1974.

4. NEDU Report 4-76, MK 12 SSDS, Air Mode, Technical Evaluation, 6 July 1976.

5. COMOPTEVFOR letter, Serial 797, September 21, 1977, Subject: Operational Evaluation of the MK 12 SSDS.

6. NCSC Hydrospace Laboratory Note 13-76, MK 12 Recirculator Duration Test, June 13, 1977.

7. NEDU Report 10-77, Manned Evaluation of the Prototype MK 12 SSDS, Helium-Oxygen Mode, September 1977.

8. NCSC Hydrospace Laboratory Note 1-77, MK 12 SSDS Mixed Gas Mode and Total System and Component Pressure Drop Test, May 12, 1977.

9. NCSC Hydrospace Laboratory Note 2-77, MK 12 SSDS Ejector Development Test, February 15, 1977.

10. NCSC Hydrospace Laboratory Note 3-77, Recirculator System Flow Test (Smooth Bore Nozzle), February 9, 1977.

11. NCSC Hydrospace Laboratory Note 9-77, MK 12 SSDS Total System Flow Test Series 2, May 9, 1977.

12. NCSC Hydrospace Laboratory Note 16-77, MK 12 Emergency Mode Flow Test, April 15, 1977.

13. NCSC Hydrospace Laboratory Note 17-77, MK 12 Swan Diving Hose Pressure Drop Test, Semi-Closed Mode, April 15, 1977.

14. NCSC Hydrospace Laboratory Note 23-77, MK 12 SSDS Recirculator Canister Test, August 11, 1977.

15. NCSC Hydrospace Laboratory Note 25-77, MK 12 SSDS Recirculator Functional Characteristics Test, July 1, 1977.

16. NEDU Technical Note 1-77, MK 12 SSDS Mixed-Gas Mode Standard Navy Hose Evaluation, 29 July 1977.

17. NEDU Report 2-78, Second Manned Evaluation of the Prototype MK 12 SSDS, Helium-Oxygen Mode, 14 March 1978.

REFERENCES--CONTINUED

18. NEDU Technical Note 2-78, MK 12 SSDS Mixed-Gas Equipment Manned System Evaluation, 31 March 1978.

19. NEDU Report 20-78, Carbon Dioxide Absorbent Canister Studies of the Hot Water Heated, Helium-Oxygen Mode, MK 12 Surface Supplied Diving System, 1 December 1978.

20. NEDU, TECHEVAL TEST PLAN, MK 12 Surface Supported Diving System, Project 131-1-DT-IIIG, 15 August 1978.

21. NCSC Hydrospace Laboratory Note 5-78, MK 12 SSDS Helmet with Recirculator Noise Level Test, May 26, 1978.

22. NCSC Hydrospace Laboratory Note 3-78, MK 12 Emergency Flow Test, May 5, 1978.

23. MK 12 SSDS Test and Evaluation Master Plan, TEMP No. 131-1, revised 4 April 1978.

APPENDIX A

HUMAN FACTORS ASSESSMENT

A.1 TEST H-1, HUMAN ENGINEERING QUESTIONNAIRE RESULTS

Table A-1 lists divers' evaluations of MK 12 SSDS operational design. In general, the divers stated that the MK 12 was outstanding in every way, it was excellent overall, and they would like to try it wearing a wet suit in moderate water. Table A-2 provides tenders' assessments of MK 12 operational design.

A.2 TEST H-2, PERSONNEL AND TRAINING REQUIREMENTS

Table A-3 provides divers' operation and training assessment; Table A-4 lists maintenance training assessment results.

TABLE A-1. DESIGN FOR OPERATION, DIVERS' VIEWPOINT

Helmet Assembly	Satisfactory	Warrants Improvement	Improvement Mandatory
Communications[1]	66.6%	26.6%	4.8%
Exhaust Valve	95.2%	4.8%	
Supply Valve	100 %		
Noise Level	100 %		
Dress Assembly			
Breech Ring	100 %		
Sizing	90.4%	9.6%[2]	
Zipper	95.2%	4.8%	
Harness Interface	66.0%	44.0%[3]	
Weight Selectivity	95.2%	4.8%	
Weight Distribution	95.2%	4.8%	
Gas Leaks	95.2%	4.8%	
Boots			
Weight	100 %		
Ease of Donning/Doffing	100 %		
Comfort	90.4%	9.6%[4]	
Recirculator			
Emergency Bottle Operation	52.4%	47.6%[5]	
Recirculator Valve Operation	90.5%	9.6%	

1/All divers judged the party line capability of this communication station excellent.

2/These divers were not within the average diver size limitation.

3/During TECHEVAL, harness buckles were inadvertently reversed.

4/These divers had out-of-diver community sizes (extra wide).

5/Valve accidentally opened during TECHEVAL; it has been modified.

TABLE A-1. DESIGN FOR OPERATION, DIVERS' VIEWPOINT—CONTINUED

Recirculator	Satisfactory	Warrants Improvement	Improvement Mandatory
Harness Interface	85.6%	14.4%[6]	
Canister Dust	100 %		
Backpack Comfort	100 %		
Stability	100 %		
Ease of Donning/Doffing	100 %		
Overall Comfort	100 %		
Control Identification	100 %		
Mixed Gas			
Overall Mobility	100 %		
Overall Comfort	100 %		
Overall Control	100 %		
Weight Distribution	100 %		
Weight Selectivity	100 %		
Procedures			
Predive	95.2%	4.8%	
Turnaround	100 %		
Canister Cleaning	100 %		
Postdive	100 %		
Surface Decompression	100 %		
Normal Operating	100 %		
Emergency	100 %		

6/Harness has been modified since TECHEVAL.

TABLE A-2. DESIGN FOR OPERATION, TENDERS' VIEWPOINT

Helmet	Satisfactory	Warrants Improvement	Improvement Mandatory
Attachment, Open Circuit	95.2%		4.8%
Attachment, Mixed-Gas Hoses	80.8%	19.2%[1]/	
Breech Ring Mating	100 %		
Harness Hardware	61.6%	38.4%	
Ease of Donning/Doffing	95.2%	4.8%	
Boots			
Ease of Donning/Doffing	100 %		
Recirculator			
Ease of Donning	95.2%	4.8%	
Ease of Doffing	100 %		
Helmet Attachment	90.4%	9.6%[2]/	
Leak Test	100 %		
Gas Supply Hose Attachment	90.4%	9.6%	
Harness Interface[3]/	90.4%	9.6%	
Backpack[4]/	95.2%	4.8%	

[1]/These tenders thought snagging was possible during salvage operations.

[2]/These tenders thought the recirculator hoses might be cut or torn during salvage operations.

[3]/Since TECHEVAL, lengthening the straps has been considered.

[4]/Improvement has been initiated since TECHEVAL.

TABLE A-2. DESIGN FOR OPERATION, TENDERS' VIEWPOINT--CONTINUED

Procedure	Satisfactory	Warrants Improvement	Improvement Mandatory
Predive[5]/	90.5%	9.6%	
Turnaround	100 %		
Canister Cleaning/Filling	95.2%	4.8%[6]/	
Postdive	95.2%	4.8%	
Surface Decompression	100 %		
Normal Operating	100 %		
Emergency[7]/	95.2%	4.8%	

[5]/Changes have been made since TECHEVAL.

[6]/Prepacked canisters were recommended as being cost beneficial.

[7]/The emergency valve has been modified since TECHEVAL.

TABLE A-3. OPERATIONS AND TRAINING ASSESSMENT QUESTIONNAIRE RESPONSES

1. Can you satisfactorily operate the MK 12 diving system?
   Response: 100% Yes - No - No comment

2. Do you have confidence in the performance of this system?
   Response: 100% Yes - No - No comment

3. Would you have been able to operate the MK 12 diving system without formal training?
   Response: 45.5% Yes 45.5% No 9% No comment

4. Did you have any difficulty deciding what action was necessary to properly use the MK 12 diving system?
   Response: 18.2% Yes 77.3% No 4.5% No comment

5. Did you have any difficulty using the communications support equipment?
   Response: 36.4% Yes 59.1% No 4.5% No comment

6. Is there any specific knowledge not covered in formal training that you found you needed to operate the equipment?
   Response: 9.1% Yes 90.9% No - No comment

7. Do you believe that your MK 12 operational training on the equipment is adequate?
   Response: 90.9% Yes 9.1% No - No comment

8. Do you believe that your MK 12 diving system training is adequate to cope with emergency situations?
   Response: 95.5% Yes 4.5% No - No comment

9. Are your techniques for operating the MK 12 diving system different from those taught?
   Response: 18.2% Yes 77.3% No 4.5% No comment

10. Are your techniques for operating the MK 12 diving system different from those in the technical manual?
    Response: 4.5% Yes 86.4% No 9.1% No comment

11. Are there any conditions under which you consider the MK 12 too tiring (fatiguing) to operate?
    Response: 9.1% Yes 90.9% No - No comment

12. What changes would you make to your formal training?
    Response: 59.1% Commented 40.9% No comment

13. Please make any additional comments that you consider pertinent to the MK 12 SSDS that have not been covered.
    Response: 22.7% Commented 77.3% No comment

TABLE A-4. MAINTENANCE TRAINING ASSESSMENT QUESTIONNAIRE RESPONSES

1. Do you consider your maintenance training adequate to effectively fault detect on the MK 12 equipment?
   Response: 71.4% Yes 14.3% No 14.3% No comment

2. Do you consider your maintenance training adequate to effectively fault locate on the MK 12 equipment?
   Response: 66% Yes 19.7% No 14.3% No comment

3. Do you consider your maintenance training adequate for the parts removal, repair, and replacement work necessary for the MK 12 equipment?
   Response: 71.4% Yes 14.3% No 14.3% No comment

4. Do you consider your maintenance training to be adequate to enable you to perform the calibration required on the MK 12 equipment?
   Response: 90.5% Yes 9.5% No - No comment

5. Do you consider your maintenance training to be adequate to perform system check tests required for the MK 12 equipment?
   Response: 95.2% Yes 4.8% No - No comment

6. Without formal schooling on the MK 12 equipment, would your Navy diving experience have been adequate to enable you to satisfactorily fault detect, fault locate for this system?
   Response: 33.3% Yes 47.6% No 14.3% No comment 4.8% Questionable

7. Without formal schooling on the MK 12 equipment, would your Navy diving experience have been adequate to enable you to cope with the parts removal, repair and replacement work necessary for the system?
   Response: 52.4% Yes 33.3% No 14.3% No comment

8. Without formal schooling on the MK 12 equipment, would your Navy diving experience have been adequate for you to understand the calibration procedures associated with this system?
   Response: 42.9% Yes 38.1% No 14.2% No comment 4.8% Questionable

9. Without formal schooling on the MK 12 equipment, would your Navy diving experience have been adequate to enable you to grasp the equipment checkout test procedures?
   Response: 61.9% Yes 23.8% No 14.3% No comment

10. Do you find the fault detection/fault locate procedures difficult to understand and/or follow?
    Response: 19% Yes 81% No - No comment

11. Do you find the parts removal, repair and/or replacement procedures to be difficult to understand and/or follow?
    Response: 14.3% Yes 85.7% No - No comment

TABLE A-4. MAINTENANCE TRAINING ASSESSMENT QUESTIONNAIRE RESPONSES--CONTINUED

12. Do you find the calibration procedures common to this system difficult to understand and/or follow?
Response: - Yes 100% No - No comment

13. Do you find the equipment checkout lists to be difficult to perform or to understand?
Response: 4.8% Yes 85.7% No 9.5% No comment

14. Did you find the formal maintenance schooling difficult to grasp and/or understand?
Response: - Yes 90.5% No 9.5% No comment

15. Is there any specific knowledge not given you in the formal training that must be acquired in order to fault detect/fault locate in the MK 12 system?
Response: 23.8% Yes 61.9% No 14.3% No comment

16. Is there any specific knowledge not given in formal training that must be acquired in order to correctly remove, repair and/or replace parts in the MK 12 system?
Response: 19% Yes 71.5% No 9.5% No comment

17. Is there any specific skill that you must acquire in order to correctly remove, repair and/or replace parts in the MK 12 system?
Response: 19% Yes 76.2% No - No comment 4.8% Questionable

18. Do the parts removal, repair and/or replacement procedures that you use differ from those recommended in:

(a) formal training?
Response: 19% Yes 81% No - No comment

(b) technical manual?
Response: - Yes 81% No 14.3% No comment 4.7% Questionable

19. Do the checkout procedures that you use differ from those recommended in:

(a) formal training?
Response: 9.5% Yes 81% No 9.5% No comment

(b) technical manual?
Response: 14.2% Yes 76.2% No 4.8% No comment 4.8% Questionable

20. Did you receive any contractor/development personnel assistance while fault detecting/fault locating the MK 12 system?
Response: 42.9% Yes 42.9% No 14.2% No comment

TABLE A-4. MAINTENANCE TRAINING ASSESSMENT QUESTIONNAIRE RESPONSES--CONTINUED

21. What changes would you like to have made to your formal (school) maintenance training on the MK 12 system?
Response: 52.4% Commented 47.6% No comment

22. What changes would you like to have made to your on-the-job maintenance training on the MK 12 system?
Response: 38.1% Commented 61.9% No comment

23. Please make any additional maintenance comments that you consider pertinent to the MK 12 that have not been covered.
Response: 14.3% Commented 85.7% No comment

GLOSSARY

ACFM	Actual cubic feet per minute (gas flow)
CO_2	Carbon dioxide
dB	Decibels
dBA	Decibels (adjusted scale A)
°F	Degrees Fahrenheit
FSW	Feet of sea water
He	Helium
HeO_2	Helium-oxygen breathing mixture
Lexan	Shatterproof polycarbonate plastic (trade name)
Mixed Gas	Any gas other than compressed air
NCSC	Naval Coastal Systems Center
NCSL	Naval Coastal Systems Laboratory
NEDU	Navy Experimental Diving Unit
NSDS	Navy School of Diving and Salvage
NWDL	Normal working dive limit
ΔP	Differential pressure
O_2	Oxygen
psi	Pounds per square inch
psig	Pounds per square inch, gauge
SEV	Surface equivalent value
SSDS	Surface Supported Diving System
SUR D	Surface decompression
Topside	Ondeck personnel and equipment of a diving station
Umbilical	Gas supply hose and communications cable
Whip	A short connecting piece of hose or cable (leader)